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Fast Charging Station for Simultaneous Recharging of Three Electric Vehicles

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Introduction

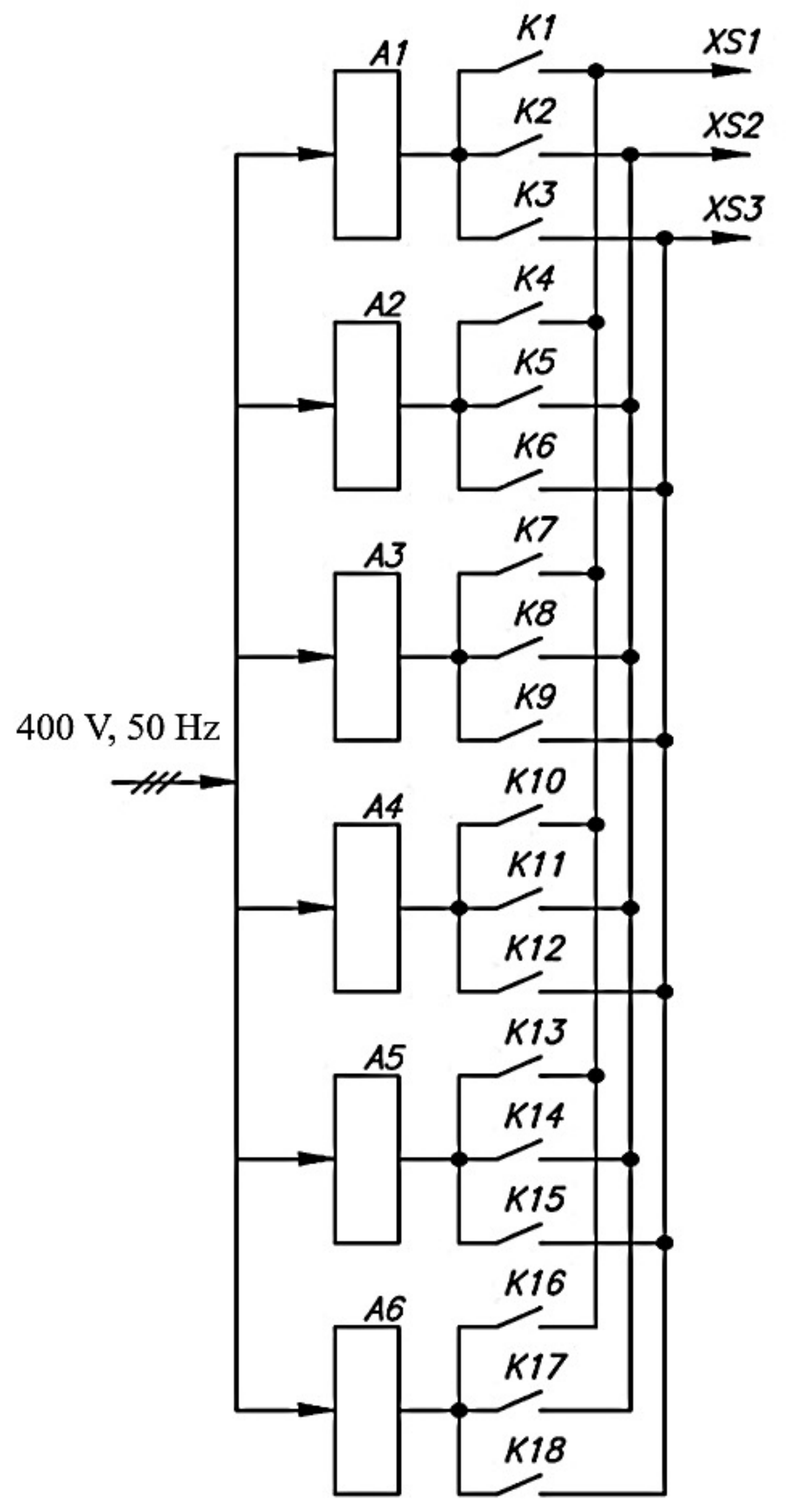
Multi-port fast-charging stations (MCS) significantly reduce the duration of multiple EVB recharging and consequently make the use of EVs more convenient and attractive. The fast-charging station **EHS-EDISON-150** is designed for **simultaneous recharging up to three electric vehicles**.

It contains **6 power units**, and **36 output contactors**, which are connected to **3 connection sockets**. The proposed algorithm for connecting the power units to connection sockets takes into account the specified current consumption limit and ensures uniform charging of the power units. It minimizes charge duration of two or three connected electric vehicle.

The proposed block diagram

1. EVB is connected to one of the free connection sockets XS1-XS3 →
2. its BMS cooperates with the MCS central control system →
3. Given BMS transmits information to the central control system (SC) about the required current and voltage to satisfy battery optimal charging →
4. SC transmits the relevant information to the corresponding power units A1-A6, which are connected to this EVB →
5. BMS of each VB controls MCS power units connected to it via SC.

- *A1-A6 – power units that convert the input three-phase voltage into DC output voltage;*
- *K1-K36 – output contactors that connect the output voltages of power units to the required connection socket XS1-XS3*



The proposed block diagram

Functioning algorithm

Proposed algorithm works as follows:

1. We measure and record the output current $I_{u\,i}$ and state B_{ij} that each power unit A1-A6 has at a given time.

2. We calculate power $P_{B\,z}$ that is currently required to recharge z-*th* batteries connected to MCS. Calculated power includes parameters that set BMS_z of connected EVB. Power is zero ($P_{B\,z} = 0$) if z-*th* battery is not connected to MCS.

3. Required input current I_{rMCS} is calculated from $I_{MCS} = \dfrac{\sum_1^z P_{B\,z}}{\sqrt{3}U_{MCS}\cdot \eta}$

4. Coefficient of possible network overload is determined:

$$\begin{cases} K_L = 1, & \text{if } \ I_{\mathrm{Mmax}} > I_{\mathrm{rMCS}} < I_{CImax}; \\ K_L = \dfrac{I_{\mathrm{rMCS}}}{I_{\mathrm{Mmax}}}, & \text{if } \ I_{\mathrm{rMCS}} \geq I_{\mathrm{Mmax}} < I_{CImax}; \\ K_L = \dfrac{I_{\mathrm{rMCS}}}{I_{CImax}}, & \text{if } \ I_{\mathrm{rMCS}} > I_{\mathrm{Mmax}} \geq I_{CImax}, \end{cases}$$

   where I_{Mmax} is maximum input current of MCS. Note maximum value I_{VCSmax} can change withing the day depending upon total capacity of network.

5. Planned current $I_{B\,z}$ for charging$z$-th battery, connected to MCS is calculated, considering:

$$\begin{cases} I_{B\,1} = K_L I_{rB\,1}; \\ I_{B\,2} = K_L I_{rB\,2}; \\ I_{B\,3} = K_L I_{rB\,3}, \end{cases}$$

   where $I_{rB\,1}$, $I_{rB\,2}$, $I_{rB\,3}$ ($I_{rB\,z}$) – required current of z-*th* battery that sets its BMS_z. If z−*th* battery is not connected to MCS connection socket relevant current $I_{rB\,z}$ is zero.

6. Planned current valuesI_{XS1}, I_{XS2}, I_{XS3} of connection sockets XS1-XS3 we equate to the corresponding current values $I_{B\,1}$, $I_{B\,2}$, $I_{B\,3}$ of the batteries connected to them.

7. We calculate difference $\Delta I_{XS\,m}$ between planned and measured current values of connection sockets XS1-XS3:

$$\begin{vmatrix} \Delta I_{XS1} \\ \Delta I_{XS2} \\ \Delta I_{XS3} \end{vmatrix} = \begin{vmatrix} I_{XS1} \\ I_{XS2} \\ I_{XS3} \end{vmatrix} - \mathbf{M_f} \times \begin{vmatrix} I_{u\,1} \\ I_{u\,2} \\ I_{u\,3} \\ I_{u\,4} \\ I_{u\,5} \\ I_{u\,6} \end{vmatrix} \qquad \mathbf{M_f} = \begin{vmatrix} f_{11} & f_{12} & f_{13} & f_{14} & f_{15} & f_{16} \\ f_{21} & f_{22} & f_{23} & f_{24} & f_{25} & f_{26} \\ f_{31} & f_{32} & f_{33} & f_{34} & f_{35} & f_{36} \end{vmatrix}$$

8. Any difference $\Delta I_{XS\,m}$ is greater than zero, then in the order of the connected EVs we close such output contactor so that the power unit having the state B_{i0} is connected to the connection socket corresponding to this difference. If there is no power unit in the state B_{i0} , we connect a power unit that has the state B_{i1}.

9. Planned current values I_{XS1}, I_{XS2}, I_{XS3} are uniformly distributed between power units that are connected to relevant connection sockets. The control system of each power unit limits the output current to the maximum permissible value.

10. After a given time interval, the specified actions are repeated from the first step of the developed algorithm.

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Prototype

The proposed algorithm was verified through MATLAB/Simulink-based computer simulation and then used in a multi-port fast charging station **EHS-EDISON-150 type** – designed and manufactured by **Charge Evolution ltd** (Moscow, Russian Federation).

This station was exhibited in the **Skolkovo Innovation Center** (Moscow).

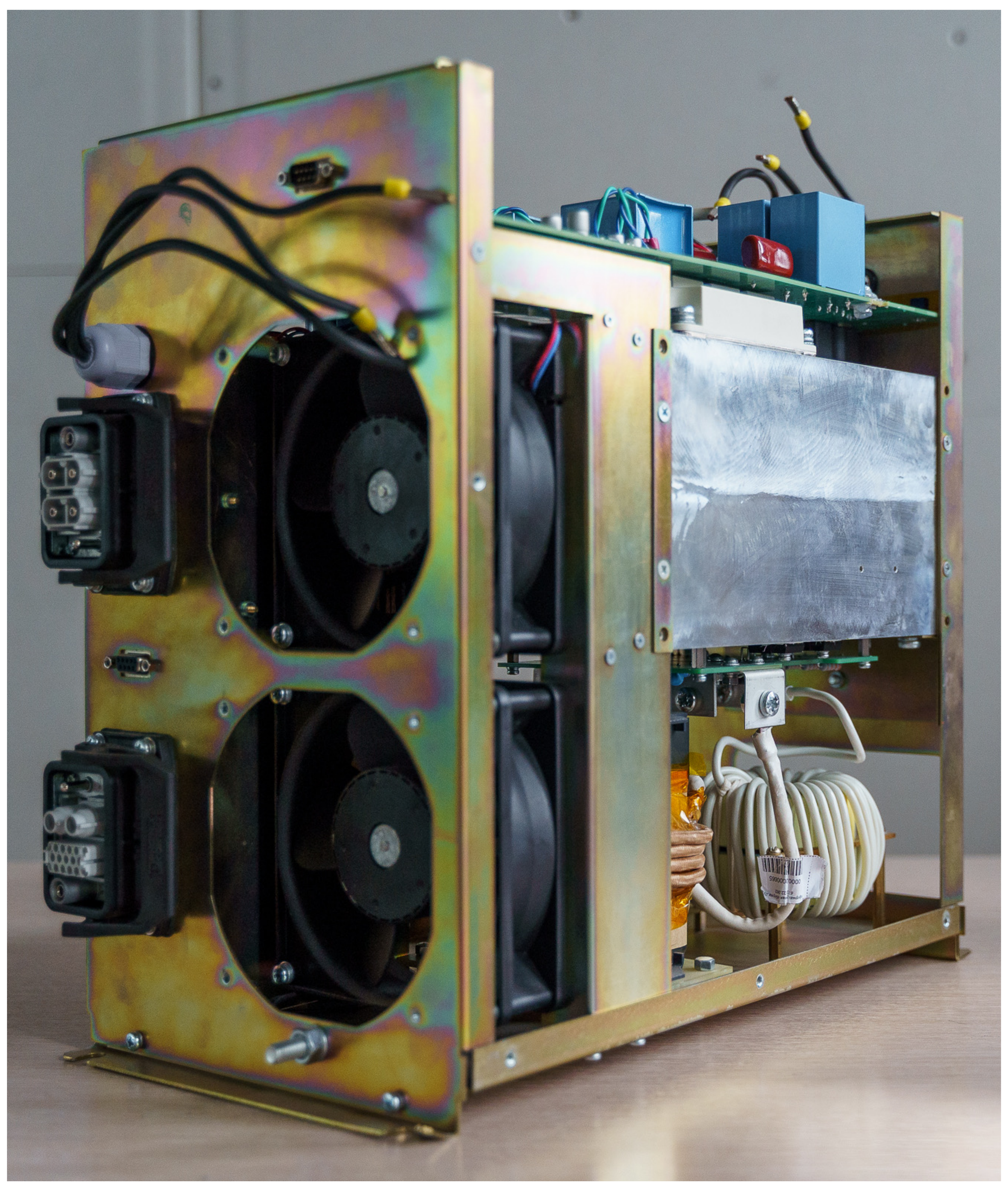
It has a switching and control unit (SCU), 6 power units (PU25), 18 output contactors and 3 connection sockets.

In designed ES-EDISON-150 are used **PU25**, in the output stages of which DC-DC VS topology is applied.

Each PU25 has:

- converting of electric current frequency of 40 kHz
- output maximum voltage equal to 1000 VDC
- output power of 25 kW
- 3 similar connection sockets CCS Combo Type 2
- mass 21 kg

Multiport charging station EHS-EDISON-150



PU25 without casing

During testing, we assumed that each EVB have a SoC of 40% at the beginning of charging and they should have a SoC of 100% at the end of charging. At the same time, the EVB voltage varied from 670 to 1000 V. Also, we set the maximum MCS power consumption from the input three-phase network equal to 120 kVA.

The conducted testing confirmed that due to the use of the developed algorithm, the consumption current from the input three-phase network does not exceed the set level when charging three EVB simultaneously. The charging time of the batteries of three EVs simultaneously is reduced by 17%, compared to the charging of two EVB simultaneously at a given limitation of the current consumption.

The first experience of EZS-EDISON-150 confirmed the performance and efficiency of the developed algorithm.

Conclusion

The developed MCS, which has short recharging time for multiple EVs, cost-effective and compact design compared to a single-port charging station, is an effective solution for places with heavy electric vehicle traffic and can promote the widespread deployment of EVs.